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REPORT OF

LABORATORY ACCEPTANCE TEST FOR TIGRIS

to the

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Report of Laboratory Acceptance Test for TIGRIS

A laboratory acceptance test for the TIGRIS system was conducted on September 17, 1964 at the RCA Astroelectronics Division plant near Princeton, New Jersey, as required by National Aeronautics and Space Administration Contract No. NAS_w-823. In addition to the RCA staff, Professor T. Gold and Mr. S. Peale from Cornell University and Mr. E. Ott from NASA headquarters were present. The test procedures were set up and conducted entirely by the RCA staff. The results of the tests are presented below in the order in which they were carried out.

I. Preliminary test data

The following information was certified to be correct and was not demonstrated.

A. Camera Parameters

1. Lines per picture - 500 (non-interlaces, less blanking)
2. Frame time - 2 seconds
3. Exposure time - variable in the following steps: 2, 4, 6, 8, 10 and 16 seconds
4. Horizontal Scanning Rate - 250 lines/second
5. Horizontal Retrace - 6%
6. Aspect Ratic - 1:1
7. Video Bandwidth - 65 KC

B. Light box calibration

The light box was calibrated in the following fashion:

1. A Spectro photometer, Pritchard Photometer Model No. 147, AED #3989 was calibrated in the Optics Laboratory, using a calibrated light source (NBS - 7041 and Calibrated Opal).
2. The Photometer was used to check the amount of light emanating from the largest aperture existing in the TIGRIS light box.
3. Step 2 above was repeated at the next smaller aperture.
4. Step 2 above was repeated for several successive apertures, until the meter reading was not usable.
5. In each case the light level measured was approximately half that of the light level measured with the next larger aperture.
6. The following table represents the final calibration of the light box as of September 14, 1964. There are no measured values below a scene brightness of 5×10^{-5} ft lamberts because the signal from the photocell is lost in noise at lower brightness levels.

TABLE I

APERTURE NUMBER	APERTURE AREA SQ. IN.	SCENE SURFACE BRIGHTNESS, B_s 0.1 ND FILTER — CALCULATED (FOOT LAMBERTS)	MEASURED (FOOT LAMBERTS)	$I_{pc} = \frac{B_s T}{4f^2(1+m)^2}$, $T = 0.85$, $m = 0.171$, $f = 2.8$ — CAL FROM AREA (FOOT CANDLES)	CAL FROM MEAS. (FOOT CANDLES)
9	1.003	5.95×10^{-3}	5.95×10^{-3}	1.2×10^{-4}	1.2×10^{-4}
10	0.460	2.74×10^{-3}	2.95×10^{-3}	5.4×10^{-5}	5.8×10^{-5}
11	0.217	1.29×10^{-3}	1.45×10^{-3}	2.5×10^{-5}	2.9×10^{-5}
12	0.100	5.94×10^{-4}	5.5×10^{-4}	1.2×10^{-5}	1.1×10^{-5}
1	0.0464	2.76×10^{-4}	3.1×10^{-4}	5.4×10^{-6}	6.1×10^{-6}
2	0.0230	1.37×10^{-4}	1.4×10^{-4}	2.7×10^{-6}	2.8×10^{-6}
3	0.0105	6.25×10^{-5}	5×10^{-5}	1.2×10^{-6}	1.0×10^{-6}
4	0.00482	2.88×10^{-5}		5.7×10^{-7}	
5	0.00215	1.28×10^{-5}		2.5×10^{-7}	
6	0.001	5.94×10^{-6}		1.2×10^{-7}	
7	0.00044	2.62×10^{-6}		5.2×10^{-8}	
8	0.000228	1.35×10^{-6}		2.7×10^{-8}	

A few minor corrections were made in the calculated columns to make the table self consistent. It was assumed that the aperture areas are correct as given for these corrections. Apparently the surface brightness for the largest aperture was established using the calibrated photocell. The calculated value of surface brightness for a smaller aperture is then the product of the ratio of the given aperture area to the largest aperture and the brightness for the largest aperture. The photocathode illumination, I_{pc}, is then determined by the given formula. Maximum errors appear to be about 15 to 20%.

This light box calibration is of course very critical in the evaluation of test results. A rough check of this calibration was made by assuming a luminous efficiency of 8 lumens per watt input for the 100 watt bulb operated at 70 watts and a 50% transmission for each of two sheets of Opal glass diffuser. (The luminous efficiency for 100 watt bulb operated at full power is about 16 lumens per watt input. (Handbook of Chemistry and Physics)). These values yield a test pattern brightness for the largest aperture of 1.5×10^{-2} ft. lamberts, which is a factor 2.5 above the final RCA calibration. However, the assumptions of 8 lumens per watt and 50% transmission for the Opal diffusers could easily be in error by a sufficient amount to give this much discrepancy. In view of the fact that the RCA values for the illimination were determined by an independently calibrated photocell, the given calibration is probably substantially correct.

II. Information capability vs. integration time.

By increasing integration time for a given light level more charge is accumulated on the I/O target with a resulting increase in modulation of the I/O beam. Ideally, the signal should increase linearly with integration time, but the finite conductivity of the target allows the charge distribution to spread which results in a degradation of the signal. The purpose of this test was to determine the effect of this lateral charge spread on the video amplitude. Electronic adjustments were avoided in the test by decreasing the light level by approximately a factor 1/2 for each doubling of the integration time. The test pattern used in the test was a bar chart of infinite contrast which is the same one used for resolution studies.

If the calibration of the light box given in section I is used, the following table describes the data. The video amplitude is peak to peak measured on an oscilloscope. Throughout the test the resolution remained a marginal 315 lines or a good 225 lines. The entries in the last column of Table II are normalized to 2.5×10^{-6} ft.-c.-sec. An absolutely linear increase in information with integration time is represented by a constant video amplitude in this column. The approximately 4% variation in the figures of the last column of table II is well within the errors of the light box calibration. The integration characteristic is therefore almost linear up to 16 seconds integration time, which meets the contract requirement.

TABLE II

Integration time (sec.)	P.C. Light Level (ft. candles)	Energy Rec'd/area (ft. candles-sec)	Video amplitude (volts)	Corrected Video Amplitude
2	1.25×10^{-6}	2.5×10^{-6}	0.9	90
4	5.7×10^{-7}	2.4×10^{-6}	0.85	.93
8	2.5×10^{-7}	2.0×10^{-6}	0.75	.93
16	1.2×10^{-7}	1.92×10^{-6}	0.7	.91

III. Signal to noise ratio.

The image orthicon beam was set to just discharge the highlights of the bar chart test pattern with an illumination of 1.2×10^{-5} ft. candles on the photocathode. The repetitive scan or 2 second integration mode was used. Under these scan conditions the peak to peak noise was measured on the oscilloscope by eliminating all light from the camera. The light was then reapplied and the peak to peak signal was measured on the scope with all adjustments remaining indentical with those of the noise measurements. The following ratio was obtained.

$$\frac{\text{Peak to Peak Signal}}{\text{Peak to Peak Noise}} = \frac{3.5}{1}$$

The formula used for calculating the signal to noise ratio in decibels is

$$\frac{S}{N} = 20 \log \frac{\text{Peak to Peak Signal}}{(\text{Peak to Peak Noise})/6} ,$$

where

$$\frac{\text{Peak to Peak Noise Voltage}}{6} = \text{rms noise voltage}$$

With this definition of rms voltage, the expression for S/N is that given by the Radio and Television Engineers' Reference Book, for television applications.[1] Experimental values for the ratio

1. E. Molloy Ed., George Mewnes LTD.

of the amplitude range between 3.4 and 4.5[2]. If account is taken of the facts that not quite the highest noise peaks are seen on the oscilloscope and that the measurement of the noise was peak to peak and hence twice the amplitude, the above derivation of rms noise voltage is reasonable. Application of the above formula to the measured ratio yields

$$\frac{S}{N} = 26.4 \text{ db}$$

which exceeds the contract specification of 20 db by 6.4 db.

IV. Horizontal Resolution Measurements.

This test was conducted with the infinite contrast bar chart as the test pattern, where vertical lines or bars were arranged in groups. Two adjacent groups of lines were separated from one another by wider spacing than appeared in either of the two groups. The density of the lines expressed as the number of lines per total horizontal picture width varied from a minimum of about 100 to a maximum of over 600. The resolution for a given light level was then determined by noting the last group of lines in the direction of increasing line density which were resolved in the oscilloscope trace of the video signal. The oscilloscope was chosen for this test in place of the monitor in order to avoid confusing the resolution of the monitor system with that of the I/O camera.

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2. S. Goldman, Frequency Analysis, Modulation and Noise, McGraw-Hill, N. Y. Toronto, London, 1948, P. 245.

As the minimum integration time of the system was 2 seconds while the contract specifications called for one second integration times for specified light levels these specific light levels were approximately halved to compensate. The following table lists the contract requirements and the demonstrated capabilities of the system.

TABLE III

Highlight Energy per Unit Area of PC.		Resolution	
Contract Spec.	Actual Calibration	Contract Spec.	Demonstrated
1×10^{-5} ft.-c-sec.	1.1×10^{-5} ft.-c-sec.	500 lines	550 lines
5×10^{-7} ft.-c-sec.	5.0×10^{-7} ft.-c-sec.	200 lines	225 lines

Table III indicates that the system exceeds the contract resolution specifications.

V. Grey step measurements.

The test pattern used for this test consisted of 11 steps of 0.1 neutral density per step filters arranged as shown in Figure 1.

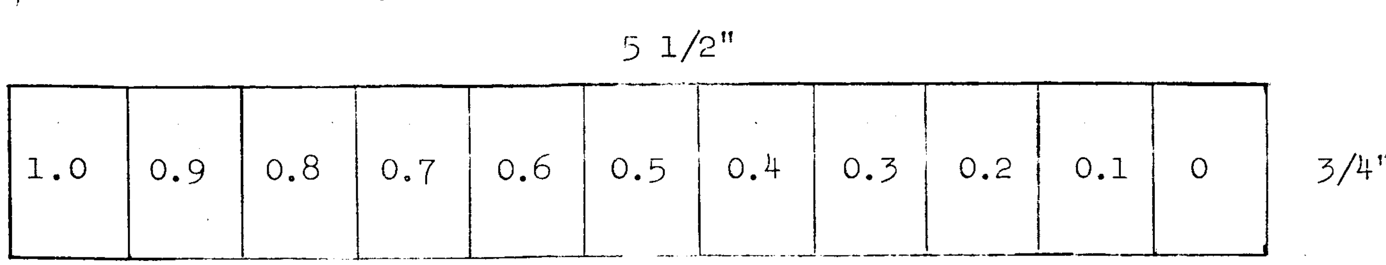

Figure 1

The dimensions given are approximate, but it is recalled that the total length of the pattern was a little over half the total width of the optical field of about 8 inches square at the test pattern position. The contrast between adjacent steps in the series is given by

$$\frac{10^{0} - 10^{-0.1}}{10^{-0.1}} = \frac{1 - .794}{.794} = .26$$

With the light level set for 5.6×10^{-6} ft-candles illumination on the photocathode from the clear window of the series of neutral steps, about 8 grey steps could be detected on the monitor screen. This determination was based on actual brightness differences between steps, as an attempt was made to eliminate the influence of the lines between adjacent steps which were evident on the monitor. Examination of the test-chart indicated that these lines may have been caused by scattered light from the edges of the film strips used for the neutral density steps.

The contract is somewhat vague as far as the grey step specification is concerned. Although the contract specifies that ten steps be discernible, whether these steps be taken above a given light level or below is not specified. The test was conducted such that the steps were taken below a 5.6×10^{-6} foot-candle photocathode illumination with the result that 8 distinct steps were discernible. Had this illumination been placed in the middle or near the most dense end of the grey scale there would have been no difficulty in displaying 10 grey steps.

During the grey step measurements a horizontal band which was darker than the reference black level of the screen extended on both sides of the horizontal band of grey steps. Rotating the grey step chart slightly indicated that the dark band was associated with the brightest steps of the grey level chart and was thus a failure of the DC restoration circuit to return the video signal to the correct black level after the bright spot encounter. It was agreed by all parties concerned that this difficulty in the D. C. restoration circuit should be corrected before the New Mexico tests.

It is seen above that the TIGRIS system has successfully met all the contract specifications if the discussion about the grey step measurements is kept in mind. It is therefore recommended that the system be accepted.

November 17, 1964

Date

Thomas Gold

T. Gold, Scientific Program Director